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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 421

Spins and maneuvers

THE NATURE OF AIR FLOW ABOUT THE TAIL OF AN AIRPLANE IN A SPIN

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Washington
May, 1932

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SUMMARY

Air flow about the fuselage and empennage during a high-angle-of-attack spin was made visible in flight by means of titanium-tetrachloride smoke and was photographed with a motion-picture camera. The angular relation of the direction of the smoke streamer to the airplane axes was computed and compared with the angular direction of the motion in space derived from instrument measurement of the spin of the airplane for a nearly identical mass distribution. The results showed that the fin and upper part of the rudder were almost completely surrounded by dead air, which would render them inoperative; that the flow around the lower portion of the rudder and the fuselage was nonturbulent; and that air flowing past the cockpit in a high-angle-of-attack spin could not subsequently flow around control surfaces.

INTRODUCTION

The results of various measurements of the attitude and motion of an airplane during the spin are now available, and, aided by our general knowledge of flow about bodies having shapes similar to those presented by the elements of an airplane while spinning, it is possible to construct a hypothetical picture of the nature of the flow about the parts of the airplane. Such a picture is, however, usually very indefinite in many of its details, and is useful for only the most general deductions. The experiments to be described herein were planned to furnish more definite information on the nature of the flow of the air around the empennage and fuselage of an airplane spinning at a high angle of attack. It was believed that the information thus obtained would be of value in studying the cause of the ineffectiveness of controls in the spin and in clarifying conflicting ideas on this subject.

At the outset it was evident that making the air stream visible so that it could be observed and photographed would be the most suitable method. The results of previous tests indicated that from a consideration of ease in handling and visibility attained a photographic method employing smoke generated by titanium tetrachloride would be satisfactory. In the use of titanium tetrachloride it was necessary, however, to construct a special type of smoke generator to meet the requirements of these particular tests.

APPARATUS AND METHOD

The smoke-generating apparatus consisted of a mixing tube, a reservoir for the reagent, and a reducing valve and tubing for using the compressed air in the engine air-starting system to force the reagent slowly into the mixing tube. The Venturi-shaped mixing tube was free to rotate and align itself with the wind in a plane parallel to the plane of symmetry of the airplane.

The airplane used for the tests was one which had been used in previous spin tests and found to spin normally at about 55° angle of attack. From such spins it recovered normally in 1 to 1-1/2 turns.

A spring-driven, solenoid-operated motion-picture camera was used to photograph the smoke streamers. The camera was mounted at the left tip of the lower wing for some of the tests and at the center section of the upper wing during the remainder of the tests. Because it was not convenient to mount two cameras simultaneously at these points, two tests were made for each spin condition so that pictures from each point could be secured.

The airplane with the generator and motion-picture camera mounted on it and details of the generator and camera mountings are shown in Figure 1.

The tests were conducted with the smoke generator mounted in three positions on the left side of the fuselage which were as follows: first, generator about midway between the trailing edge of the lower wing and leading edge of the stabilizer; second, generator near the leading edge of the stabilizer so that the smoke streamer would be di-

vided and flow over and under the surface; and third, about 9 inches aft of the trailing edge of the lower wing. In each case the boom supporting the generator was clamped just beneath the lower longerons and extended out from the side of the fuselage so that the generator axis was about 12 inches outboard from the side of the fuselage.

The angular relation of the smoke streamer to the axes of the airplane was determined for the portion of the smoke streamer directly ahead of the leading edge of the stabilizer by measuring the angle of the smoke streamer relative to a reference in the photograph, and determining the angles of the camera axes relative to the airplane for the two positions of the camera. The computations were rigorous in that they took into account these angular settings of the camera and perspective effects.

RESULTS

Reproductions of selected frames of the motion-picture film are shown in Figures 2 to 8. Dash lines were inked on the prints at the boundaries of the smoke streamer or smoke-filled wake behind airplane elements wherever the sky was the background in order to avoid losing these outlines in the printed reproductions. With the exception of these lines, however, no retouching was done on the photographs.

Computation of the direction of the smoke flow was made only for the first position of the generator because the flow was affected too much by turbulence in the other generator positions. The results for this case expressed in terms of angle of attack and angle of sideslip referred to the airplane axes at the position of the smoke streamer are given in the following table. For comparison the table also shows the directions of motion in space of the corresponding point on the smoke streamer derived from the results of previous tests employing the instrument measurements as described in reference 1.

	From smoke streamer		From instrument records	
	Right spin	Left spin	Right spin	Left spin
Angle of attack α	58°	70°	57°	67°
Angle of sideslip β	24°	12°	29°	7°

The condition of the airplane was the same in the instrument and smoke tests except for the presence of the smoke generator and camera in the latter tests, and as the moments of inertia were nearly equivalent, the motion of the airplane during the smoke tests can be considered the same as that measured with the instruments. The differences in the values obtained by the two methods, barring errors, represent the angular influence of the presence of the airplane on the direction of the air flow at the point measured.

The sequence of four views taken during the entry into a left spin (figs. 8a, 8b, 8c, and 8d) is interesting in that it shows several details in the transition from low angle of attack to high angle of attack in the spin.

DISCUSSION

The most striking demonstration made by these pictures is the extent of the "blanketing" of the fin and rudder in the very high angle-of-attack spin. Blanketing has long been recognized as a factor determining the efficiency of the fin and rudder in a spin, and some of these photographs show the outlines of the zone of dead air surrounding the fin and upper part of the rudder. They show also that the flow under the stabilizer and elevator is smooth (a small straight filament of smoke under the stabilizer plainly visible in the photograph for fig. 4b may not be discernible in the printed reproduction).

The existence of a large body of dead air above the stabilizer and elevator and of smooth flow underneath indicates that the parts of the fin and rudder situated above the stabilizer must be practically inoperative at very high angles of attack for their intended functions and that whatever fin and rudder effect is obtained in the spin is to be attributed to the air forces acting on the side of the fuselage and the portion of the rudder below the elevator. The futility of attempting to increase the fin effect or rudder control in a high-angle-of-attack spin by enlargements to the fin or rudder made above the horizontal surfaces is demonstrated by these results. The results likewise show the reason for the success of the tests with stabilizer and elevator placed at the top of the fin and rudder as described in reference 2.

The results show further that the flow about the fuselage is not seriously turbulent except near the wings where it is broken up by the presence of the latter. It may be seen also from these photographs (figs. 2b, 3b, 4b, 5b and especially figs. 6 and 7) that disturbances of air flow caused by conditions in the vicinity of the cockpit could not in any way affect the air forces acting on the control surfaces. This result is of interest since it has been proposed that one factor responsible for the few known spontaneous recoveries from "flat" spins after the pilot had despaired of recovering by using the controls and had stood up preparatory to jumping was the deflecting or disturbing by the pilot's body of air flowing past the cockpit and subsequently around the control surfaces. The directions of the flow shown by the smoke streamers make such an hypothesis improbable.

Further use might advantageously be made of this technic in studying certain phases of spinning. The experience in these tests demonstrating that moderate precautions against the corrosive action of titanium tetrachloride were sufficient, will eliminate most of the objection to its use and in some degree accelerate the work of the tests. Tests of a similar nature should be made with an airplane which spins at low angles of attack relative to the range of values at which spinning has been observed in order to determing whether serious blanketing of the fin and rudder occurs in such spins. The most profitable use of the technic, however, would be derived in its use as a guide in altering the control surfaces for the purpose of improving their

efficiency. Some encouraging results have already been obtained by altering empennage design, and undoubtedly more improvement could be secured by a further study of the subject.

National Advisory Committee for Aeronautics,
Langley Memorial Aeronautical Laboratory,
Langley Field, Va., May 3, 1932.

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1. Soulé, Hartley A., and Scudder, Nathan F.: A Method of Flight Measurement of Spins. T.R. No. 377, N.A.C.A., 1931.

2. Stephens, A. V.: Free-Flight Spinning Experiments with Several Models. R.&M. No. 1404, British A.R.C., 1931.

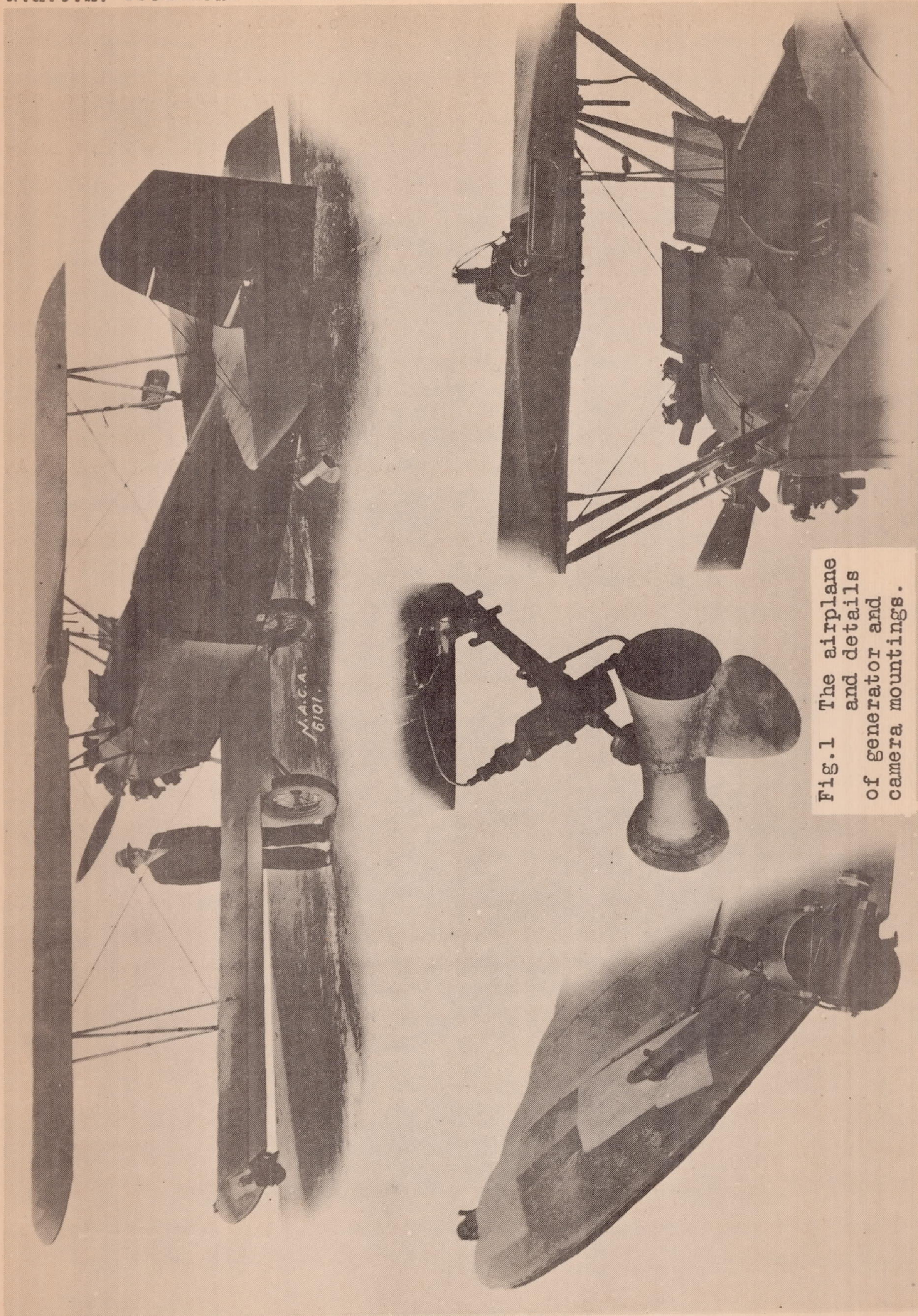
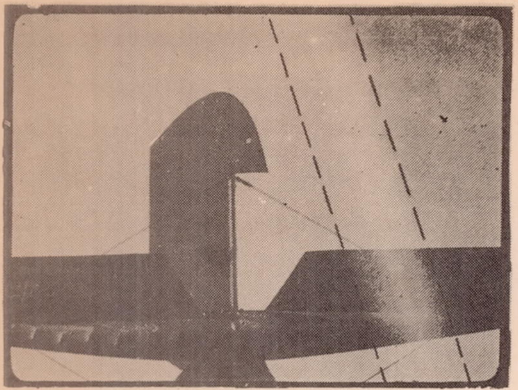


Fig.1 The airplane and details of generator and camera mountings.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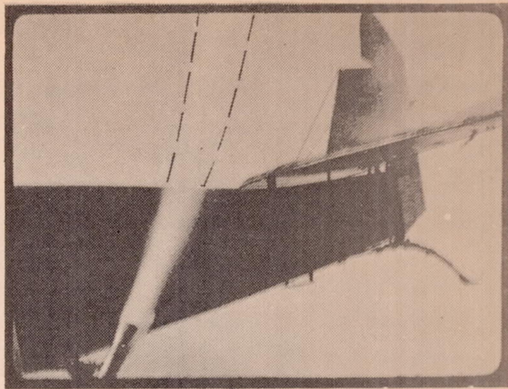
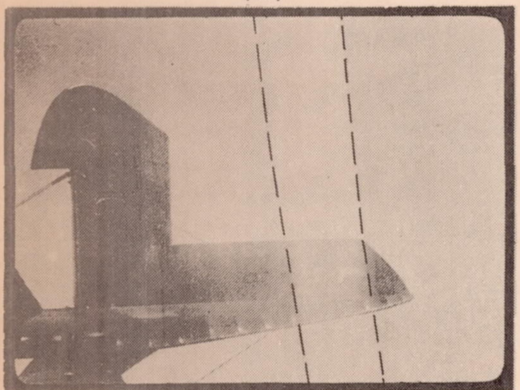

(b)

Fig.2 Flow patterns for right spin and generator at first position.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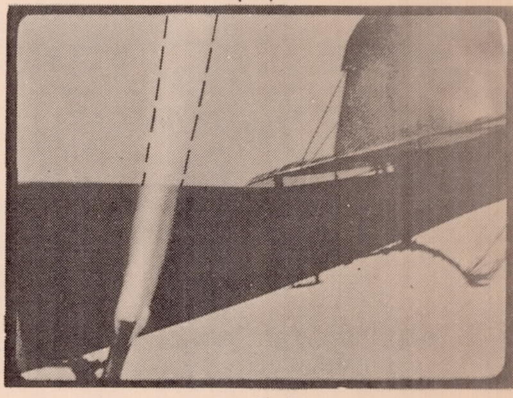
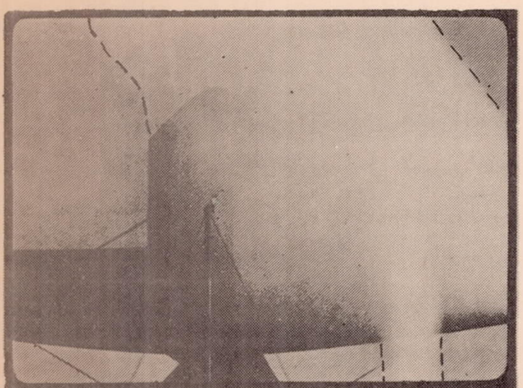

(b)

Fig.3 Flow patterns for left spin and generator at first position.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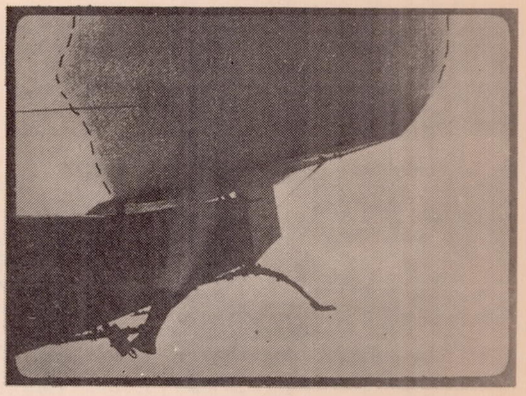
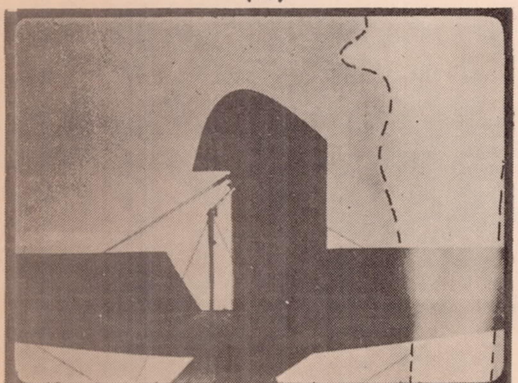

(b)

Fig.4 Flow patterns for right spin and generator at second position.


(a)


(b)

Fig.5 Flow patterns for left spin and generator at second position.

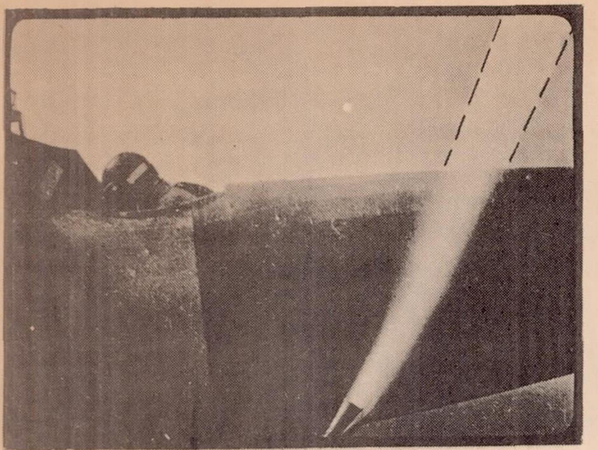


Fig.6 Flow pattern for right spin and generator at third position.

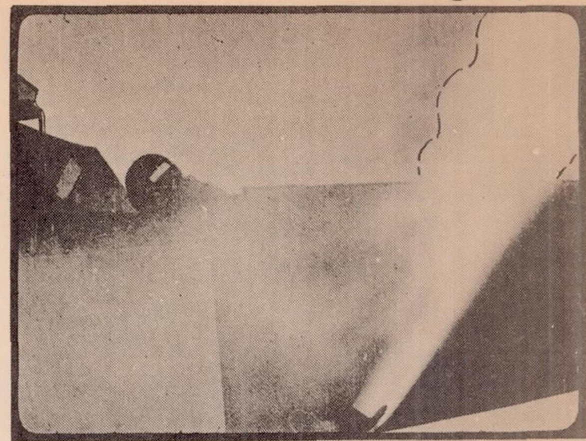
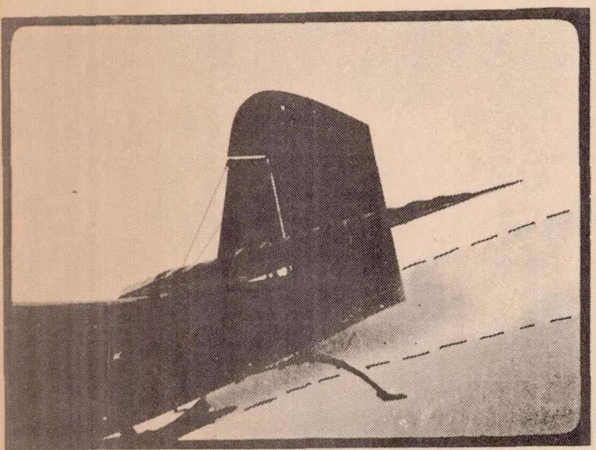
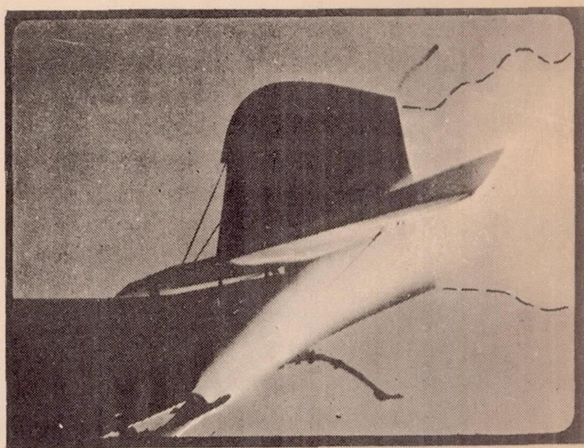


Fig.7 Flow pattern for left spin and generator at third position.



(a)



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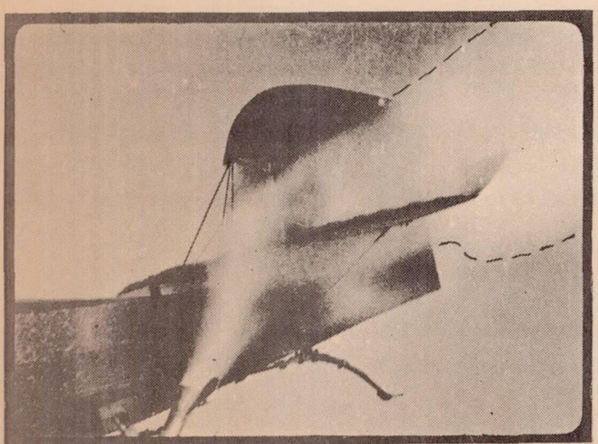
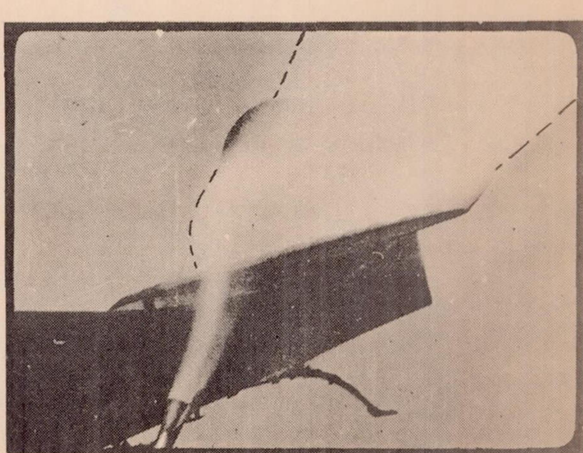


(c)



(d)

Fig.8 Flow patterns for entry into left spin with generator at second position.